The CalWater-2 field campaign: an opportunity for evaluation of moisture products in extreme environments.

NASA Sounder Science Team Meeting

Wednesday, Oct. 1, 2014, 3:40 pm

Chris Barnet

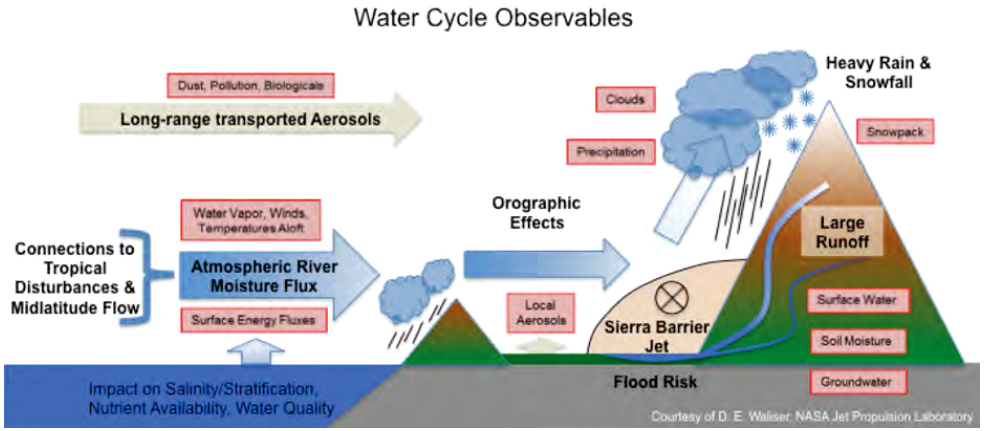
With lots of help:
NUCAPS product graphics: Colby Francoeur (STC summer intern)
Direct Broadcast Implementation: Thomas King and Letitia Soulliard (STAR), James Davies and Liam Gumley (CIMSS)
CalWater-2 Early Start Campaign: Ryan Spackman (STC)
NUCAPS AWIPS Initiative: Bill Sjoberg and Brian Motta (NOAA)

Discussion Points

- Brief introduction to atmospheric rivers (ARs)
- CalWater 2 Early Start Campaign, Feb. 2014
  - NUCAPS support of flight planning
  - Comparisons of NUCAPS to CalWater drop-sondes
- CalWater 2 Campaign, Jan/Feb 2015
  - Observing Platforms
  - Synergy with NUCAPS validation

Understanding Atmospheric Rivers (ARs) has national and societal value

- ARs are narrow filaments of enhanced WV transport
  - responsible for ≈ 90% of mid-latitude transport (Zhu 1998 MWR)
  - 75% is below 2.25 km altitude

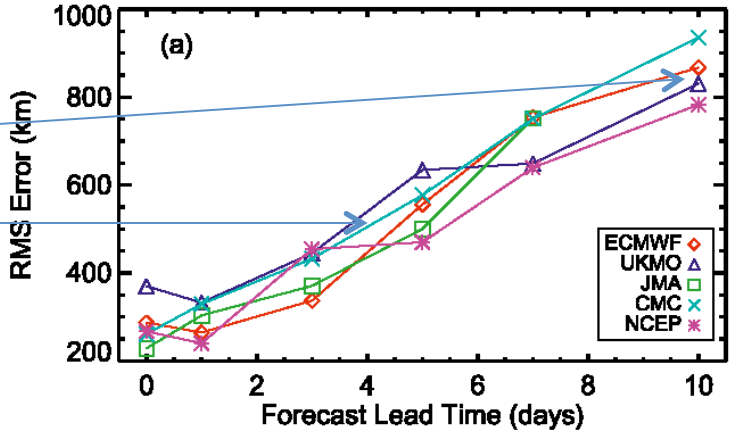


30-50% of annual precipitation on USA west coast is associated with ARs

- Typically within a few extreme precipitation events
  - Jan. 6-8, 2009 a strong event damaged the Hansen Dam (White 2012 BAMS)
  - Warm moist conditions in ARs can accelerate snowmelt
- Northwest USA snowfall tends to come in a few powerful winter Ars
  - Winter snowpack provides 70-90% of water supply for western USA
- AR events end ~40% of Northern California droughts (Dettinger 2013 J.Hydro.)
- Large ARs transport 13-26 km^3/day, ~7.5-15 times the average discharge of the Mississippi River (Ralph 2011 Eos)

Atmospheric Rivers are difficult to forecast

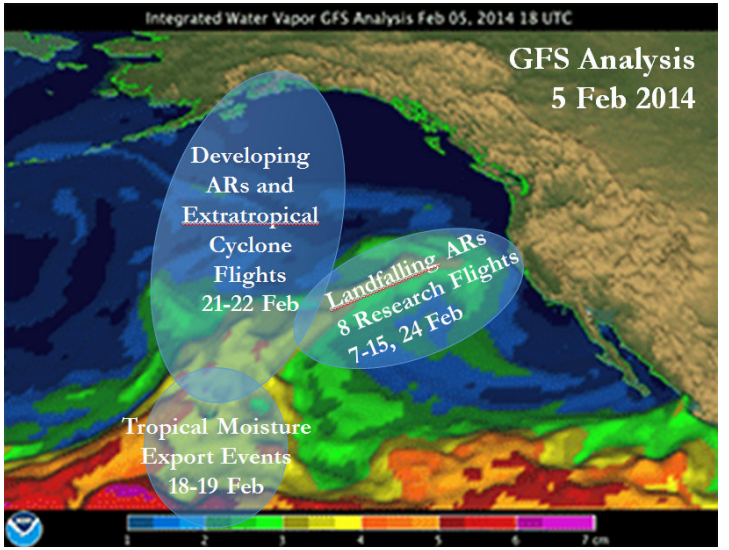
- **AR landfall forecast errors are large**
  - ~800 km at 10 day lead-time
  - 3-5 day forecast (~500 km) comparable with hurricane track errors (Wick 2013 Wea. & For.)



- Calwater 1 field campaign (2009-11) demonstrated that local aerosols and Sierra Barrier Jet plays a major role in modulating orographic precipitation
  - Aerosols carried in long-range flow was shown to affect land-falling ARs (Creamean 2013 Science)

CalWater 2 Early Start
NOAA Gulfstream-IV Flights

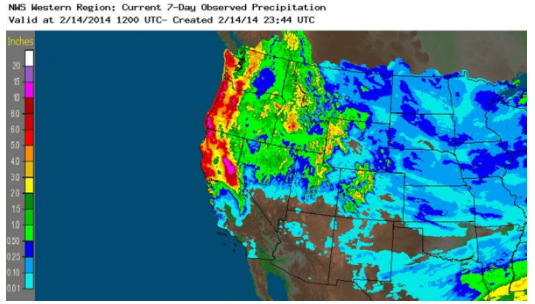
- Objective: Examine the development and structure of atmospheric rivers (ARs) before landfall to improve forecasts of extreme precipitation events along the US West Coast

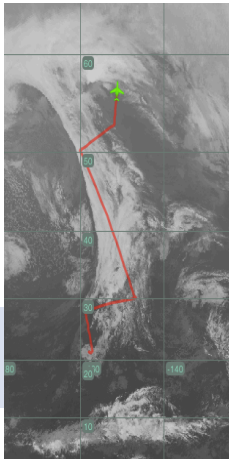


- Accomplishments:

1. 12 research flights in Eastern Pacific in Feb 2014
2. Measurements included 190 dropsondes released between 8°N – 60°N and tail doppler radar
3. Observations included:

- 2 major land-falling AR events along west coast (Feb.7-15 and Feb. 24)
  - Landfall Feb. 12, 5-10" of rainfall
  - 1st rainfall of the year for many places
- A developing AR between Hawaii, Alaska and the AR source region between Hawaii and the ITCZ (4 research flights, Feb. 18-22)

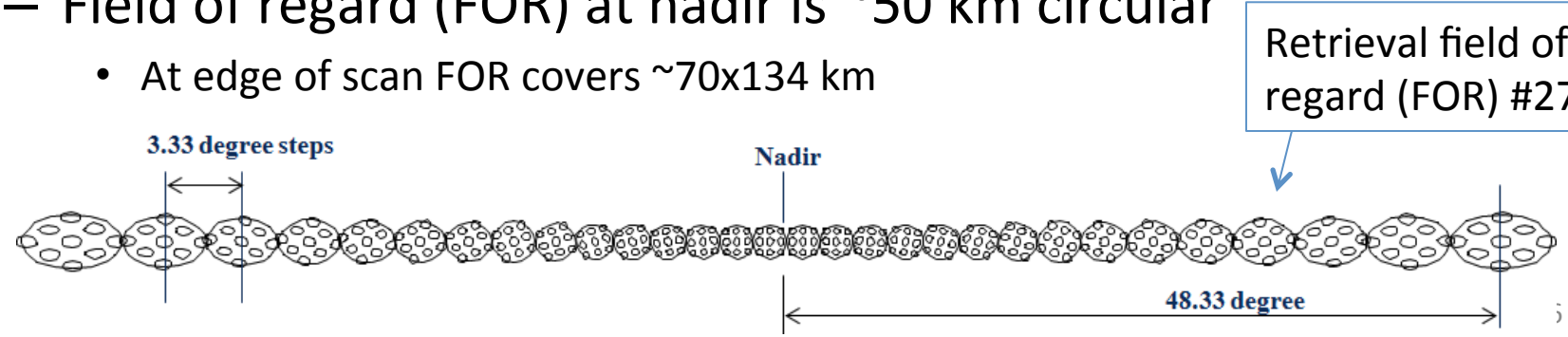




Flight Track (HI to AK) – Poleward developing AR

Retrievals can provide *situational awareness*

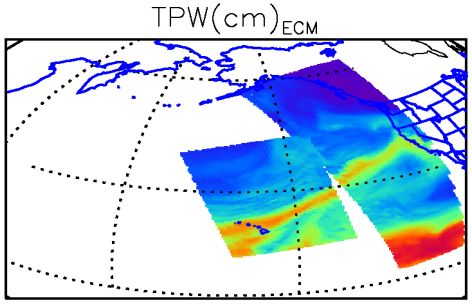
- During *CalWater 2 Early Start* field campaign STC provided retrievals with ≈8 hour latency
  - For CalWater-2 (Jan/Feb 2015) we hope to use DB with ≈15 minute latency to the pilot
- CrIS+ATMS "scanset" is acquired in 8 seconds
  - Scanset contains 30 NUCAPS retrievals in a swath of 2200 km
  - Each retrieval uses 9 ATMS and 9 CrIS fields of view (FOV)
  - Field of regard (FOR) at nadir is ~50 km circular
    - At edge of scan FOR covers ~70x134 km

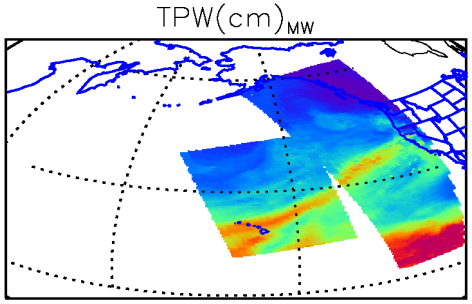


Example of NUCAPS TPW product (240 scansets are shown)

GFS and NUCAPS Total Precipitable Water Products for Feb. 8, 2014, 20 UT

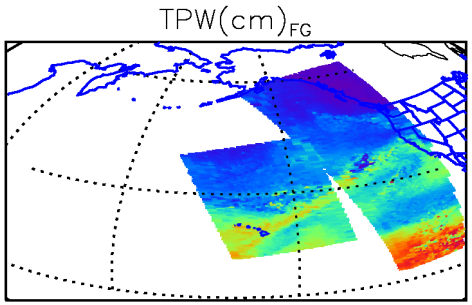
Upper Left: GFS Forecast Interpolated to FOR grid

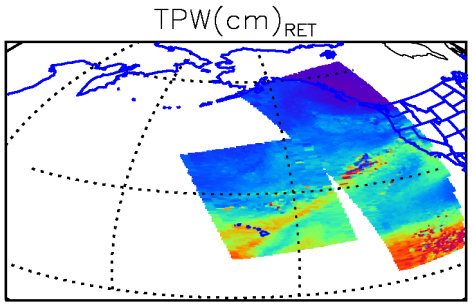




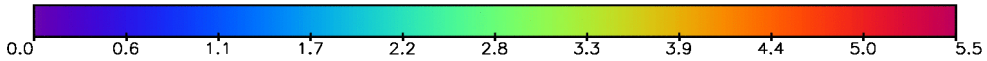
Upper Right: Microwave-Only retrieval

Lower Left: Statistical Regression retrieval





Lower Right: Microwave + infrared retrieval



Note that the regression operator (lower left) is not as spatially coherent as the microwave physical retrieval (upper right). Many of these cases are rejected (blinking FORs). The regression first guess leads the final product to have undesirable spatial structure in it. This is something CalWater can help us fix.

Example of near real time products provided to CalWater-2 on Feb. 8, 2014

Used NUCAPS science code on Univ Wisc satellite archive to process the data

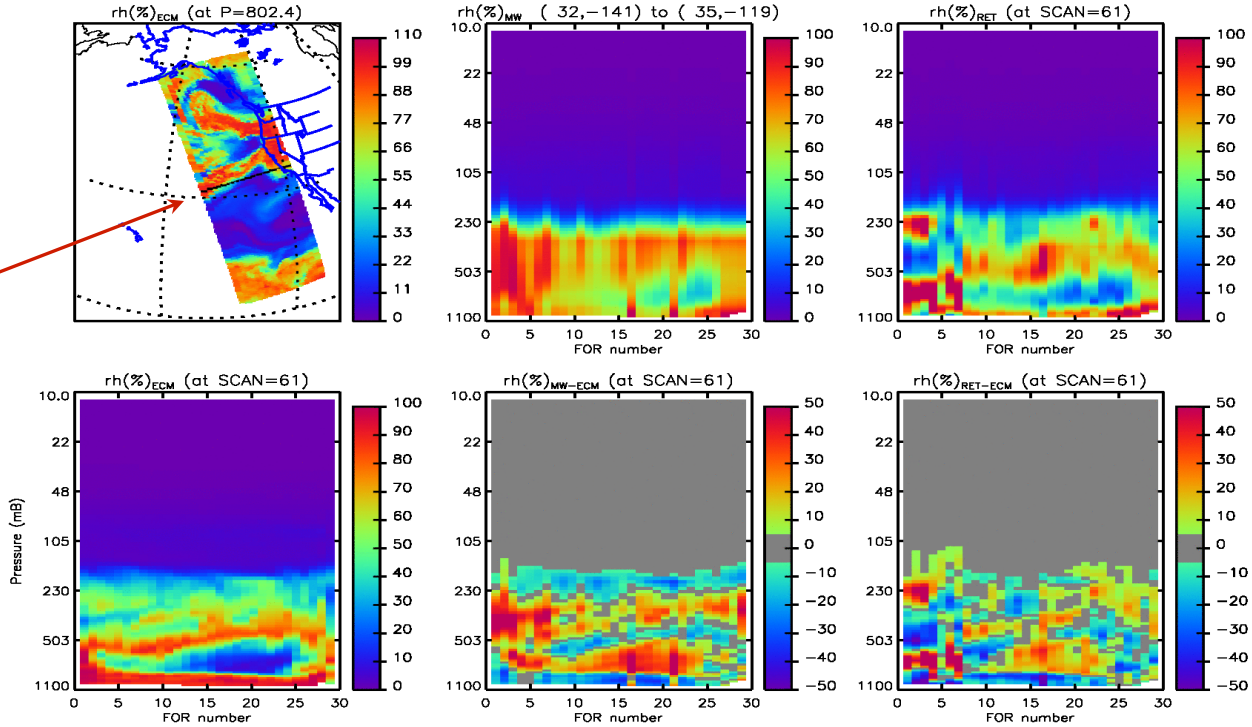
GFS forecast is interpolated to satellite time and location.

Black line is location of cross-sections in other plots

Cross-section of GFS going from west (FOR=1) to east (FOR=30)

Microwave-only retrieval

Final coupled retrieval



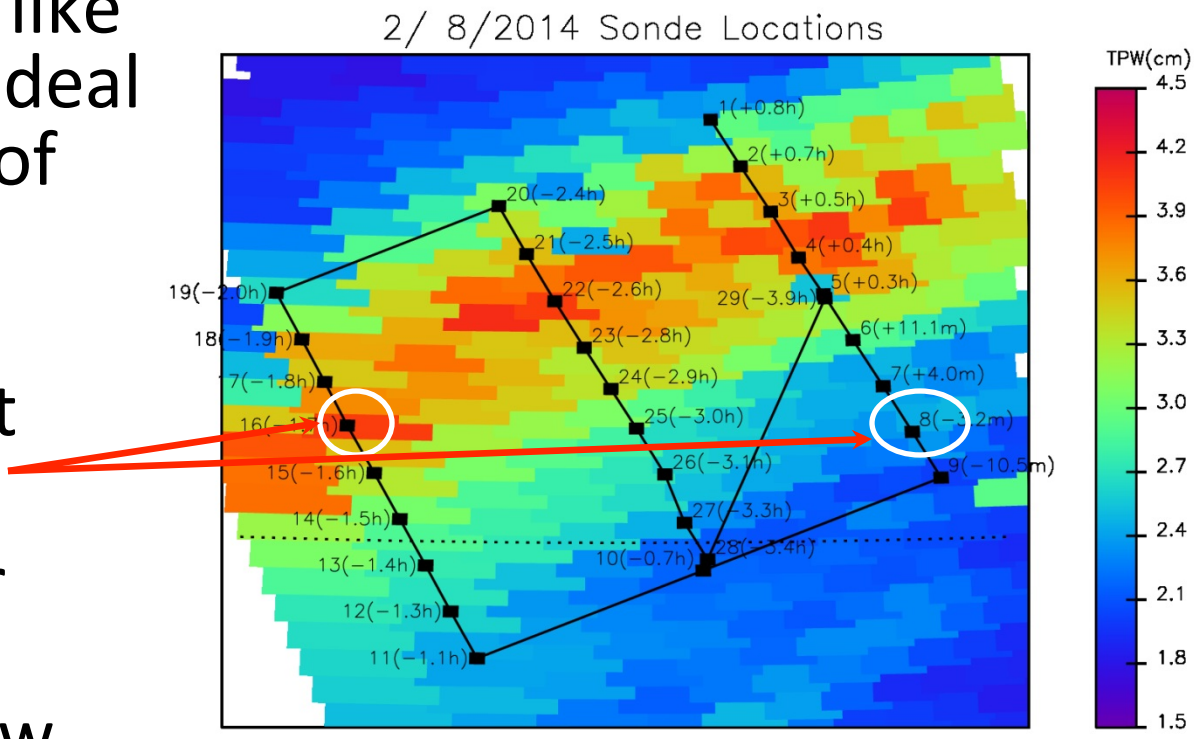
Note: Differences could be due to retrieval errors or ECMWF errors (in this case most likely the RET

Difference of Microwave-only retrieval and ECM

Difference of coupled retrieval and ECMWF

Flight pattern on Feb. 8, 2014
29 sondes were deployed

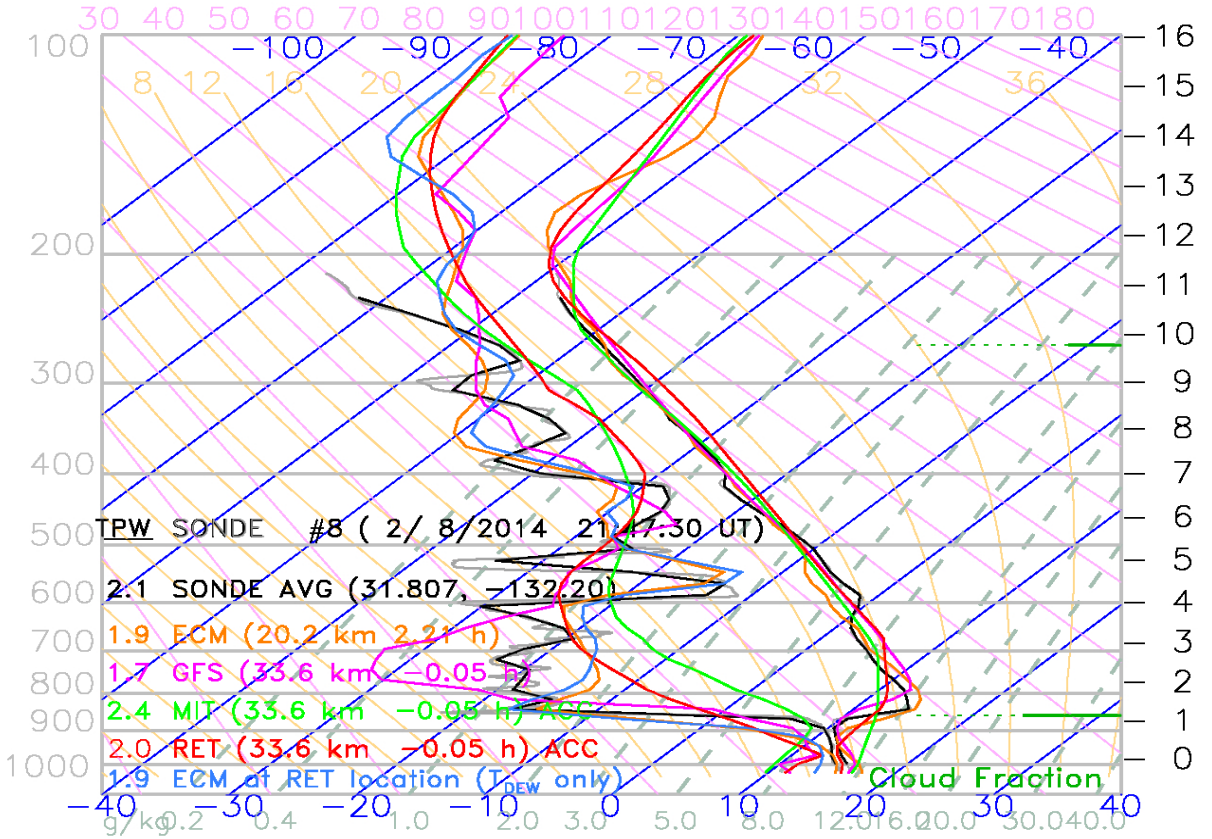
- Opportunities like CalWater are ideal for validation of products.
- Two cases are shown on next few slides
- Also useful for training and developing new user applications



Near real time retrievals were used as guidance for G-IV flight planning

Comparison to dropsonde #8 (launched 3.8 min before satellite overpass)

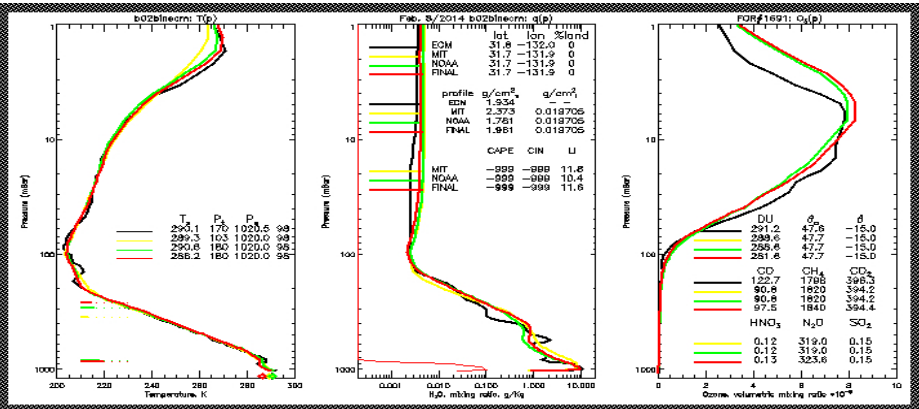
- Black = dropsonde (full-res and smoothed)
- Cyan = GFS forecast interpolated to retrieval location
- Green = uW-only retrieval
- Red = IR+uW retrieval

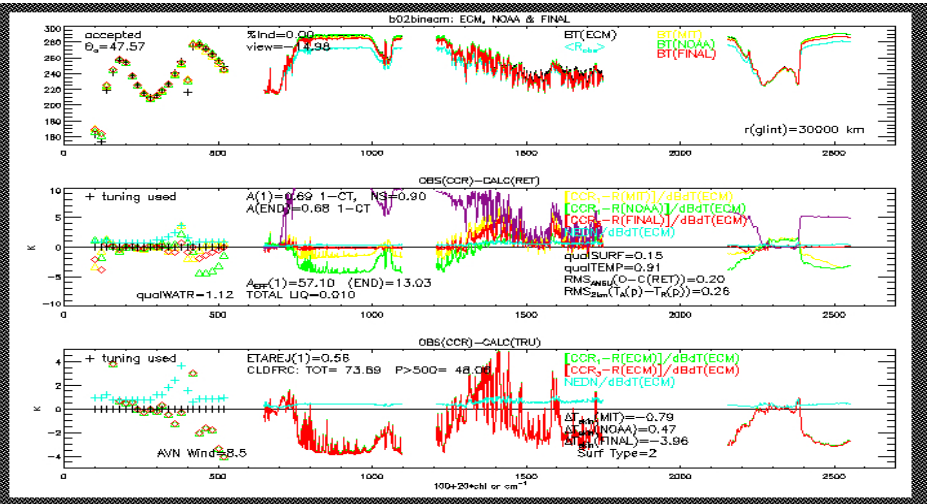


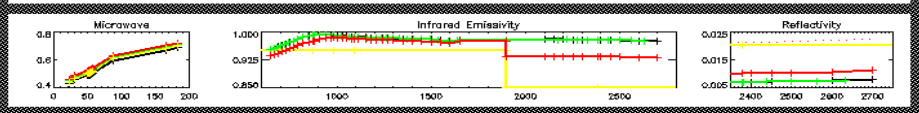
This sonde was co-located at FOR #11 in the cross-section

NUCAPS diagnostic output (closest retrieval is an *accepted* case)

- Samples the region to the south of the AR
  - Co-located ECMWF in this graphic is 2.2 hours later than retrieval





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Feb. 8/2014 b02binecm   FOR#1691    Accepted  Clearflg=T
ETAREJ(1)=0.56, ETAREJ(1)=0.56  CLDFRC: TOT= 73.89  P>500= 48.06
qualSURF=0.15  qualTEMP=0.91  qualWATR=1.12
RMS(AMSU-C(RET))=0.20, RMS(TA(p)-TR(p))=0.26
A(1)=0.69 1-CT,  NS=0.90, A(END)=0.68 1-CT,  Aeff(1)=57.10, Aeff(END)=13.03
TOTAL LIQ=0.010  AVN Winds=8.5  Surf Type=2 (water)   Ts=286.2
DTskin(MIT)=-0.79, DTskin(NOAA)=0.47, DTskin(PHYS)=-3.96
George's Test=0.180  Tsurf(PHYS)-Tsurf(REG)=-4.432
 OLR=0  h2o=0  TTp=0  TMd=2  TBt=2  Srf=2  CCR=2
  i  alat  alon %land  solz   glint R(sort)     eta %(266) %(857) Cij(850) Cij(2560)
  1  31.5-132.1   0.0  47.4     0.0   34.48  -0.152   16.7    5.5    0.00    0.00
  2  31.5-131.9   0.0  47.4     0.0   31.13  -0.026   26.1   31.4    0.00    0.00
  3  31.5-131.7   0.0  47.5     0.0   37.23   0.282    5.6   48.4    0.00    0.00
  4  31.7-132.1   0.0  47.5     0.0   32.95  -0.101   19.9   80.1    0.00    0.00
  5  31.7-131.9   0.0  47.6     0.0   27.17   0.173   41.2   16.5    0.00    0.00
  6  31.7-131.7   0.0  47.6     0.0   35.77  -0.219   10.3   63.4    0.00    0.00
  7  31.8-132.1   0.0  47.7     0.0   23.20   0.318   42.5   57.5    0.00    0.00
  8  31.8-131.9   0.0  47.7     0.0   25.04   0.248   47.1   52.7    0.00    0.00
  9  31.8-131.7   0.0  47.7     0.0   29.78   0.041   23.0   77.0    0.00    0.00
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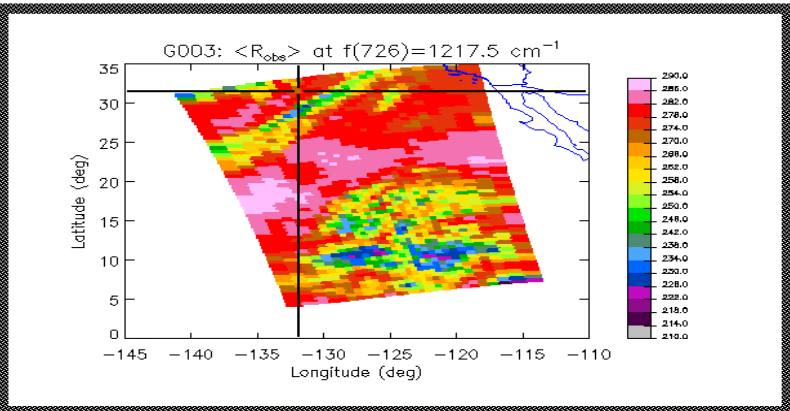
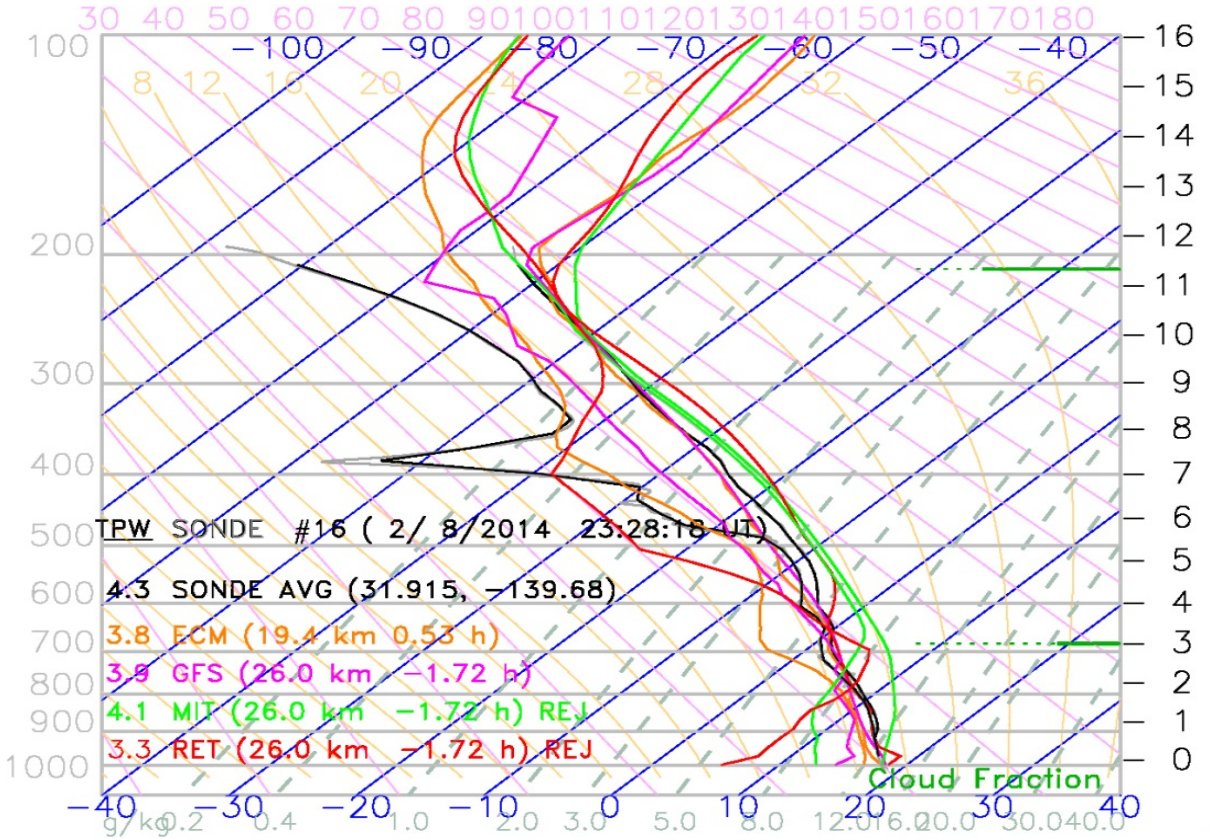


Comparison to dropsonde #16 (launched 1.7 hour after satellite overpass)

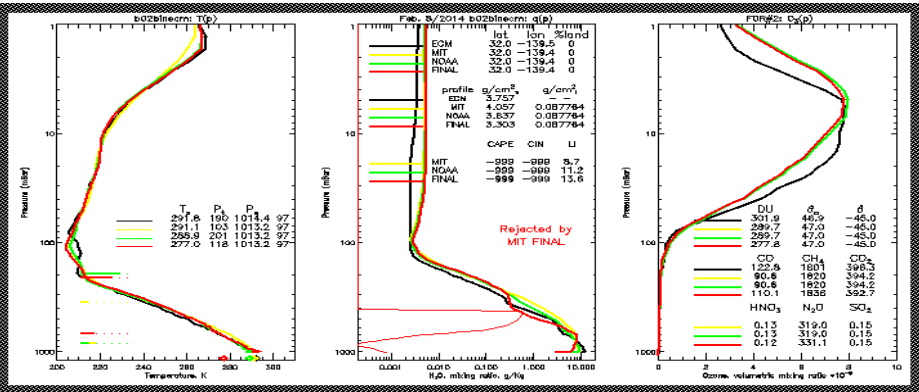
- Black = dropsonde (full-res and smoothed)
- Cyan = GFS forecast interpolated to retrieval location
- Green = uW-only retrieval
- Red = IR+uW retrieval

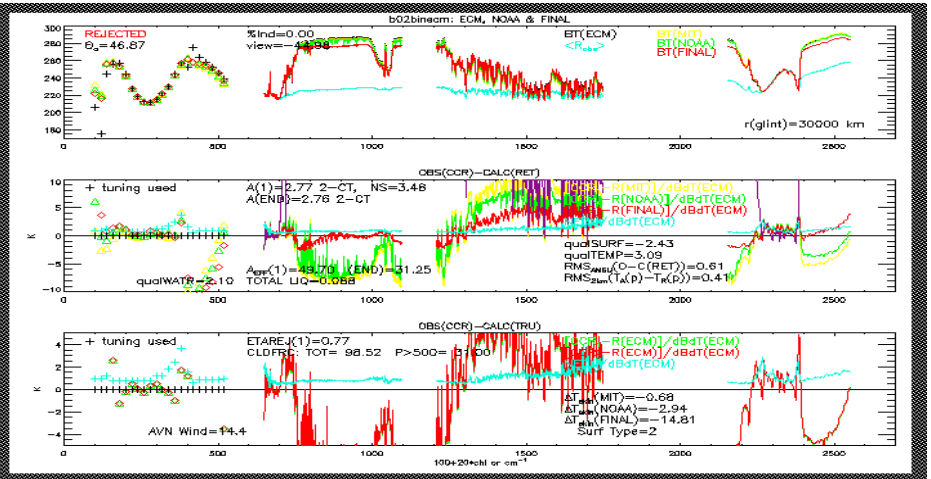


This sonde was co-located at SCAN=61, FOR #2
Example of *a rejected* IR retrieval

Diagnostic display for retrieval closest to sonde location (*rejected* case)

- Retrieval within the AR is rejected due to ~98% cloudiness, high liquid water content






```
Feb. 8/2014 b02binecm   FOR#2    Rejected  Clearflg=T
ETAREJ(1)=0.77, ETAREJ(1)=0.77  CLDFRC: TOT= 98.52  P>500= 31.00
qualSURF=-2.43  qualTEMP=3.09   qualWATR=2.10
RMS(AMSU-C(RET))=0.61, RMS(TA(p)-TR(p))=0.41
A(1)=2.77 2-CT,  NS=3.48, A(END)=2.76 2-CT,  Aeff(1)=49.70, Aeff(END)=31.25
TOTAL LIQ=0.088  AVN Wind=14.4  Surf Type=2 (water)   Ts=277.0
DTskin(MIT)=-0.68, DTskin(NOAA)=-2.94, DTskin(PHYS)=-14.81
George's Test=0.497  Tsurf(PHYS)-Tsurf(REG)=-11.863
 OLR=2  h2o=2  TTp=2  TMd=2  TBt=2  Srf=2  CCR=2
 i  alat  alon %land  solz   glint R(sort)     eta %(209) %(681) Cij(850) Cij(2560)
 1  31.8-140.0   0.0  46.7     0.0     8.05   0.530   66.2   33.8    0.00    0.00
 2  31.7-139.7   0.0  46.6     0.0    10.47   0.140   39.6   60.4    0.00    0.00
 3  31.7-139.3   0.0  46.6     0.0    19.10  -2.213   22.6   77.4    0.00    0.00
 4  32.0-139.8   0.0  46.9     0.0    10.66   0.838   35.7   64.3    0.00    0.00
 5  32.0-139.4   0.0  46.9     0.0     8.06   0.495   86.7    0.0    0.00    0.00
 6  31.9-139.1   0.0  46.8     0.0    10.48  -0.200   72.3   27.7    0.00    0.00
 7  32.3-139.5   0.0  47.2     0.0     4.86  -0.755  100.0    0.0    0.00    0.00
 8  32.2-139.2   0.0  47.1     0.0     5.43   0.364  100.0    0.0    0.00    0.00
 9  32.1-138.9   0.0  47.0     0.0     5.92   0.810   84.6   15.4    0.00    0.00
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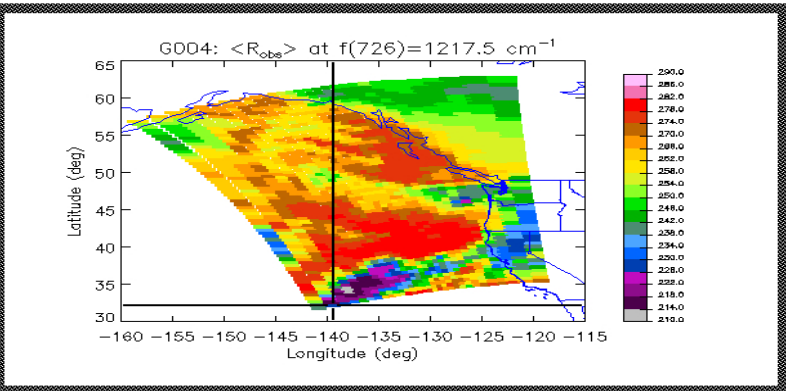
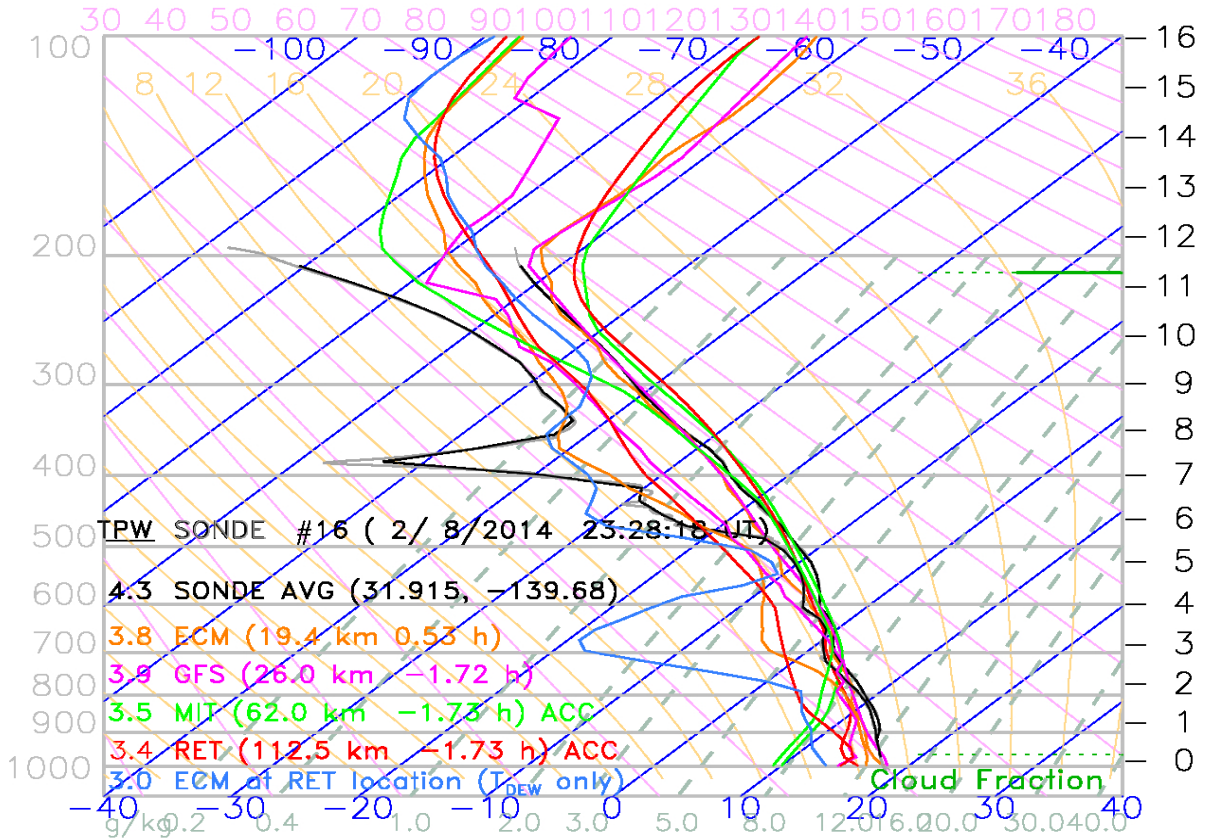


Atmospheric River sonde #16
Closest ACCEPTED retrieval

In this plot the closest accepted retrieval (red) was 113 km to the south (outside of AR)

ECMWF is also shown at the retrieval location (dashed orange) .

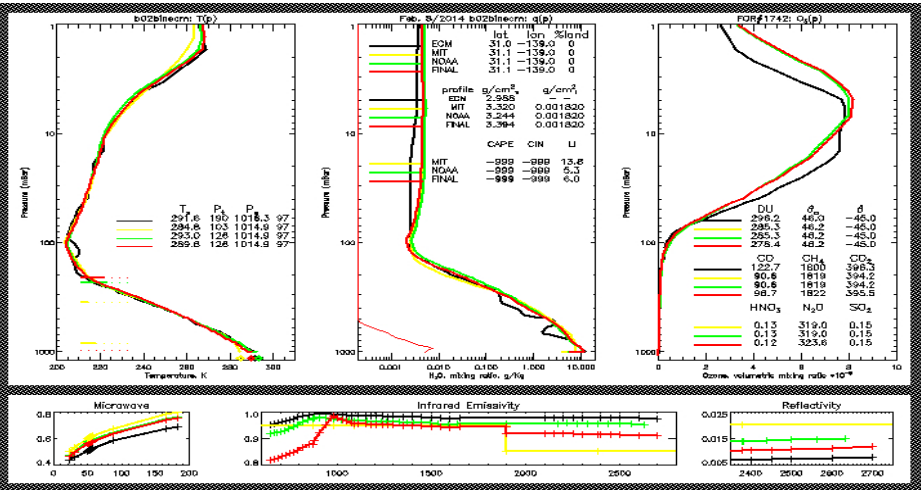
This retrieval has 3.4 cm IWV compared to 4.3 cm for the sonde and 3.0 at ECMWF co-located with the retrieval

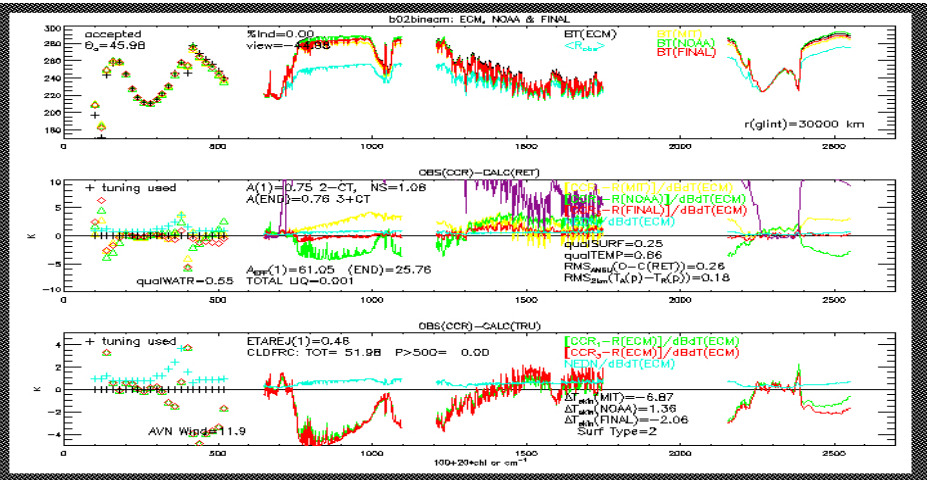


This sonde was closest to SCAN=61, FOR #2
Accepted IR retrieval at SCAN=59, FOR #2

Diagnostic output for closest *accepted* retrieval

- Closest retrieval is to the south of the AR, not relevant for this sonde



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Feb. 8/2014 b02binecm   FOR#1742    Accepted  Clearflg=T
ETAREJ(1)=0.46, ETAREJ(1)=0.46  CLDFRC: TOT= 51.98  P>500=  0.00
qualSURF=0.25  qualTEMP=0.86  qualWATR=0.55
RMS(AMSU-C(RET))=0.26, RMS(TA(p)-TR(p))=0.18
A(1)=0.75 2-CT,  NS=1.08, A(END)=0.76 3+CT,  Aeff(1)=61.05, Aeff(END)=25.76
TOTAL LIQ=0.001  AVN Wind=11.9  Surf Type=2 (water)   Ts=289.6
DTskin(MIT)=-6.87, DTskin(NOAA)=1.36, DTskin(PHYS)=-2.06
George's Test=0.126  Tsurf(PHYS)-Tsurf(REG)=-3.418
 OLR=0  h2o=0  TTp=0  TMd=2  TBt=2  Srf=2  CCR=2
  i  alat  alon %land  solz   glint R(sort)     eta %(211) %(964) Cij(850) Cij(2560)
  1  30.9-139.6   0.0  45.8     0.0    5.69   0.354  100.0    0.0    0.00    0.00
  2  30.8-139.3   0.0  45.7     0.0   12.20   0.248   76.3    0.0    0.00    0.00
  3  30.8-139.0   0.0  45.7     0.0   15.90   0.009   59.3    0.0    0.00    0.00
  4  31.1-139.4   0.0  46.0     0.0    9.87   0.205   85.3    0.0    0.00    0.00
  5  31.1-139.0   0.0  46.0     0.0   25.63  -0.233   29.0    0.0    0.00    0.00
  6  31.0-138.7   0.0  45.9     0.0   34.18  -0.355    8.0    0.0    0.00    0.00
  7  31.4-139.1   0.0  46.3     0.0   27.02   0.057   15.2    0.0    0.00    0.00
  8  31.3-138.8   0.0  46.2     0.0   25.68  -0.198   39.0    0.0    0.00    0.00
  9  31.2-138.5   0.0  46.2     0.0   19.97  -0.087   55.8    0.0    0.00    0.00
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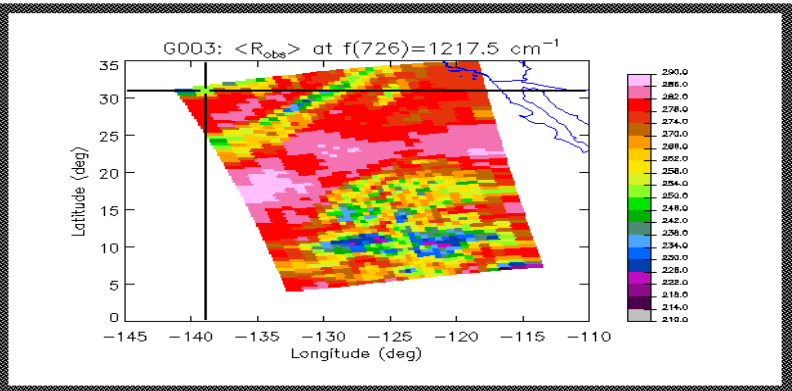
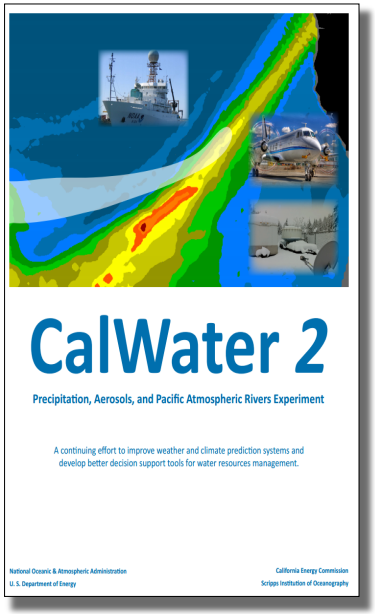
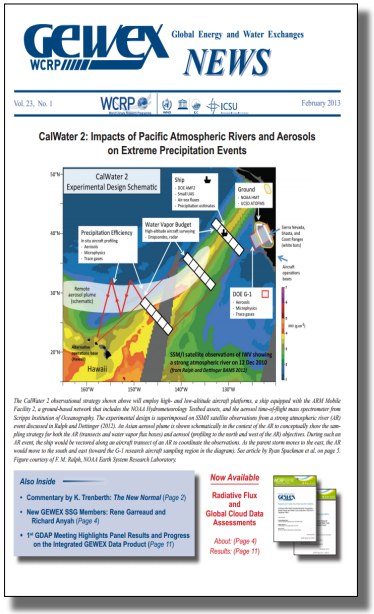


CalWater 2 Campaign Jan/Feb 2015

- CalWater 2 white paper is at http://esrl.noaa.gov/psd/calwater
- Coordinated with DOE ACAPEX (ARM Cloud Aerosol Precipitation Experiment)





What can be done for CalWater 2

- Retrieval products (T(p), IWV, q(p), O3(p), etc.) can be provided from the U.Wisc PEATE archive as was done in Feb. 2012
  - In January 2015 will have ~2 hour latency on PEATE
    - (was ~8 hour in Feb. 2014)
- Also, there are 3-4 direct broadcast sites that can provide CrIS/ATMS with ~15 minute latency
  - Each site acquires NPP within a radius of ~500 km
  - Honolulu Hawaii, Corvallis Oregon, Fairbanks Alaska
  - NRL site recently came on-line

What these products provide to the CalWater field campaign

- Satellite retrievals can provide synoptic-scale context for the sparse *in-situ* datasets
  - Retrievals can be used to characterize the regime outside the AR
  - Research retrievals can also be employed (e.g., precipitation estimates from ATMS, dust algorithms) within the AR.
- BUT --- we are only within the field region for a few seconds
  - Deploy more dropsondes with +/- 20 minutes of overpass
  - Ryan Spackman (STC at ESRL) is willing to work with us
- Aqua/AIRS research products are also available
  - This satellite has overpasses at the same time as NPP
    - Products are more mature, has cloud microphysical products
  - The Aqua orbit "slides" w.r.t. NPP
    - could improve spatial coverage

What we gain from CalWater 2

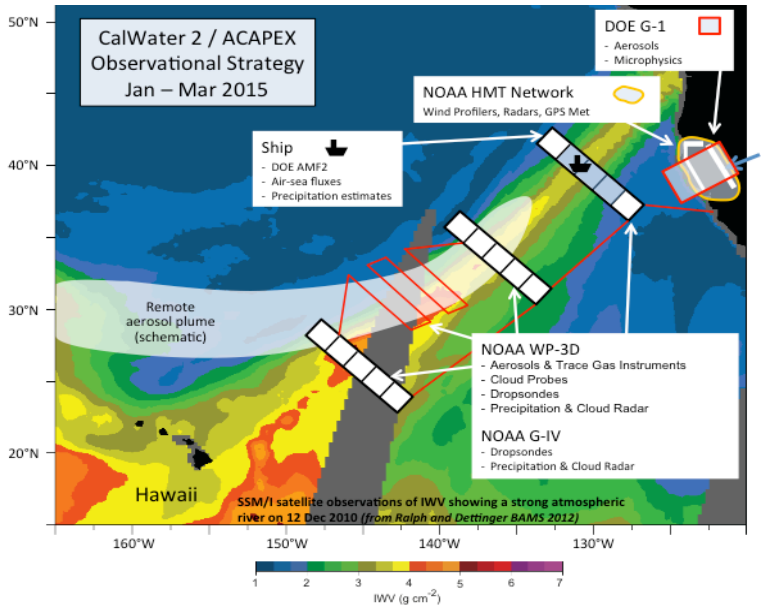
- I strongly believe that CalWater 2 is an ideal opportunity for satellite product validation
  - We test our algorithm in situations that are of national and social interest
- As algorithm developers, we need these kinds of scenes to improve the retrieval skill and tailor the quality control.
  - We can also test experimental versions of NUCAPS
    - e.g., with ATMS as a formal *a-priori* to improve spatial coherence of the product.
  - We gain the expertise of the entire CalWater science team to characterize the background environment of these scenes.
  - Other *in-situ* measurements that have been proposed (CO, O_3, CO_2, aerosols) will help the NPP validation,
  - WFO's have shown interest in NUCAPS products (via AWIPS-2)
    - this is an opportunity to demonstrate their value in the field

CalWater2 Goals and Science Questions

- Science questions:
  - Document and quantify the structure and evolution of ARs and their moisture budgets.
  - Improve understanding and modeling of the influence of the tropics, including tropical convection and the various intra-seasonal modes of variability associated with tropical convection, on extra-tropical storms and ARs
  - Characterize aerosols and their microphysical properties over the Pacific Ocean
  - Improve understanding and modeling of aerosol-cloud-precipitation interactions in clouds transitioning from the maritime regime to the orographic regime
- Goals: Improve prediction systems and develop decision support tools

CalWater 2/ACAPEX Field Campaign

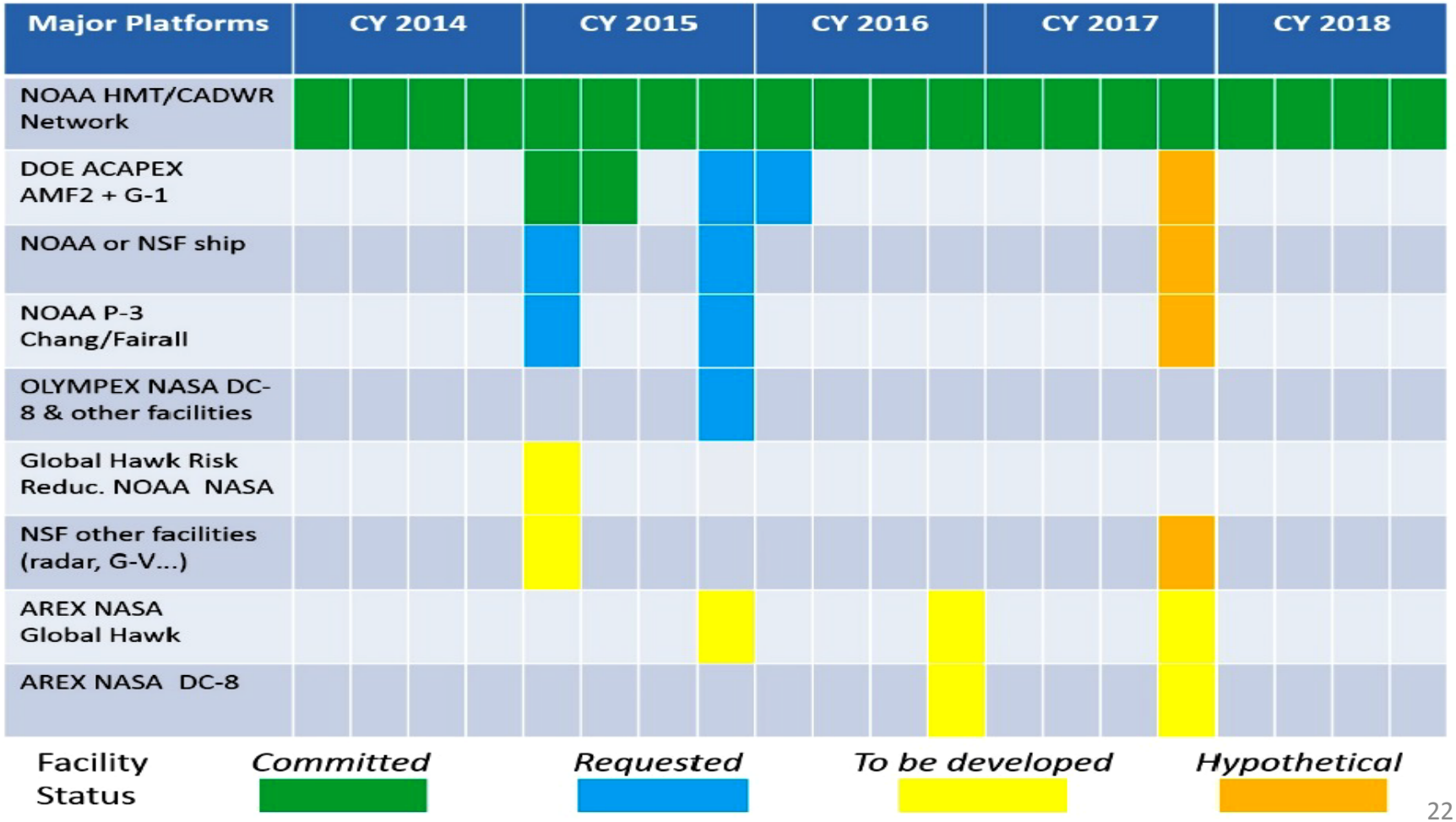
- Interagency Campaign:
  - Scripps (Marty Ralph, Kim Prather)
  - NOAA (Allen White, Ryan Spackman)
  - DOE (PI: L. Ruby Leung) ACAPEX = ARM Cloud Aerosol Precipitation Experiment
- White paper at
- http://esrl.noaa.gov/psd/calwater



Platform	Range of Obs	Expected Duration	Types of sensors
AR Observatories and Hydro-Met Testbed	ARO sites: CA(4), OR(2), WA(1)	Full campaign	Snow level radar (S-band), 449 MHz wind profilers, soil moisture, 10 meter surface tower
NOAA WP-3D	1-22 kft, 4000 km range	80h over 4 weeks	~150 dropsondes, W-band radar (clouds), IWRAP Radar, Tail Dopper Radar, Cloud Probes, SFMR
NOAA G-IV	1-45 kft	90h over 6 weeks	~300 dropsondes, Tail Doppler Radar, NOAA O3, SFMR
DOE G-1 with ~40 instruments	1-23 kft	120h over 8 weeks	Cloud properties (Liq/water content, size), aerosol properties (concentration, size, CCN), trace gases (H2O, O3, CO)
NOAA R.H. Brown	Can move ≤ 5 deg/day to stay within AR	30 days	AMF2: Aerosol Observing System, Ka ,X, W-Band Cloud Radars, DOE, Micropulse LIDAR, Wind Speed, Rain Guages RS-92 Sondes: ~260 (~half dedicated overpass time)

CalWater 2 is part of a multi-year plan

Broad inter-agency commitment: (Scripps, NOAA, DOE, NASA, NSF)



Is there interest?

- Would AIRS like to participate this campaign
  - Could participate in flight planning (need NRT)
  - Could participate in post-analysis
    - Comparisons of AIRS v6 to radiosondes
    - Comparisons of AIRS v6 to NUCAPS
  - Could test new and experimental products
    - Campaign is interested in rain, aerosol, and cloud products
- Satellite weather applications
  - Tailor the quality control and presentation of the data for forecaster applications
  - Might provide a seed for NOAA R2O and O2R training

QUESTIONS?